

THE
NATURE
OF THE
THERMOMETER
DEDUCED FROM
Sir *ISAAC NEWTON'S* SCALE
OF
DEGREES
OF
HEAT
HEREUNTO ANNEXED.



DUBLIN:

Printed by A. RHAMES, for R. GUNNE, in Capel-
Street. M.DCC.XXXI.





THE
N A T U R E
OF THE
THERMOMETER
D E D U C E D

From Sir *Isaac Newton*'s SCALE of *Degrees of Heat* hereunto annexed.



IN this Paper I shall shew how to construct and adjust Thermometers, and how to reduce their Scales to the following Scale of Sir *Isaac Newton*.

IT appears from this Scale that the Rarefaction of a given Weight of Oil is proportional to its Heat, and by Consequence putting S for the Space possessed by a given Weight of Oil

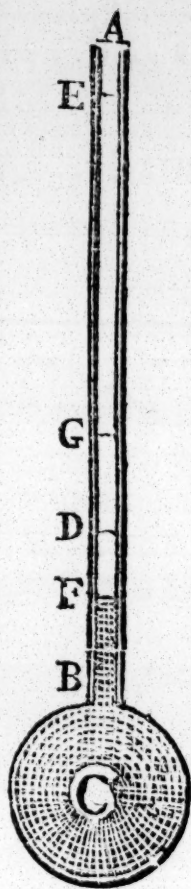
Oil when Water begins to freeze, and R for the Excess of the Space above S which it takes up when rarefied and dilated by any Degree of Heat denoted by H , $S + R$ will be the Space possessed by the Oil when rarefied by the Heat H , $S + 2R$ the Space possessed by it when rarefied by the Heat $2H$, $S + 3R$ the Space possessed by it when rarefied by the Heat $3H$, and $S + nR$ the Space possessed by it when rarefied by the Heat nH . In this Case the Rarefactions R , $2R$, $3R$, nR are proportional to the Degrees of Heat H , $2H$, $3H$, nH .

AND it is likewise true, that if a Weight of Oil denoted by W possess the Space S when Water begins to freeze and be rarefied by any Degree of Heat into the Space $S + R$, twice that Weight of Oil or $2W$ will be rarefied by the same Degree of Heat into the Space $2S + 2R$, three Times that Weight or $3W$ into the Space $3S + 3R$, and n times that Weight or nW into the Space $nS + nR$. In this Case the Rarefactions R , $2R$, $3R$, nR are proportional to the Weights of Oil W , $2W$, $3W$, nW .

THE Rarefaction of any Weight of Oil by any Degree of Heat will universally be as the Weight of the Oil and the Degree of Heat taken together, that is, R will be as $W \times H$. But W the Weight of the Oil will be as its Magnitude when its Density is given, and by Consequence will be as S the Space possessed by it when Water begins to freeze; whence R will be proportional to $S \times H$.

LET

LET ABC be a Thermometer filled with Linseed-Oil F the freezing Point or Height above the Ball to which the Oil rises when Water begins to freeze, G the Height to which it rises when rarefied by the Heat of the warmest Parts of the Surface of a human Body ; and then the Capacity of the Cylinder GF will be R the Excess of the Space possessed by the Oil when rarefied by the external Heat of a human Body above the Capacities of the Cylinder FB and of the Ball C, which Capacities added together will be S the Space possessed by the Oil when Water begins to freeze. And putting D and d for the Diameters of the Ball and Stem, and L and l for the Lengths of the Cylinders GF and FB, $0.7854d^2L$ will be proportional to $0.7854d^2lH + 0.5236D^3H$, and $1.5d^2L$ proportional to $1.5d^2lH + D^3H$, whence L will be proportional to $\frac{1.5d^2lH + D^3H}{1.5d^2}$.



By measuring the Lengths of the Cylinders and Diameter of the Stem, and computing the Diameter of the Ball, I found L, l, D, d, in Inches and decimal Parts to be 1.925, 2.425, 0.84994, 0.075. These Numbers being substituted instead of the Letters to which they are equal, 1.925 will be proportional to 902.343 if H the external Heat of the Body be 12 as in Sir Isaac's Scale, and dividing both Terms of the Ratio by 1.925, 1 will be proportional to 468.749. Having found this Ratio in one Thermometer, the Height L above the freezing Point of any other Thermometer, to which the Oil rises by any Degree of Heat expressed by H, may be had

A 3 from

from this Proportion, $1 : 468.749 :: L : \frac{1.5d^2 l H + D^3 H}{1.5d^2}$, whence $L = \frac{1.5d^2 l H + D^3 H}{703 d^2}$

nearly. And $L = \frac{D^3 H}{703 d^2}$, when l is nothing, or the freezing Point is placed at the Ball. For Example, if the Diameter of the Ball be an Inch, the Diameter of the Stem a Tenth Part of an Inch, the Heat 12, (the external Heat of a human Body) and the freezing Point be placed at the Ball; then L will be 1.7. If the Diameter of the Ball be 2 Inches, the Diameter of the Stem, Heat, and freezing Point the same as in the last Example, L will be 13.65 Inches. If the Diameter of the Ball, the Diameter of the Stem, and Degree of Heat be the same as in the first Example, and the freezing Point be an Inch from the Ball, L will be 1.73. And lastly, if the Height above the freezing Point to which the Oil rises by the Heat of the Air at Noon about *July* be 20 Inches, the Diameter of the Stem a Tenth Part of an Inch, and the freezing Point be placed at the Ball, the Diameter of the Ball will be 2.86 Inches: Therefore by the foregoing Rule Thermometers may be constructed, in which the Oil shall rise to any Height above the freezing Point by any known Degree of Heat.

A Thermometer is adjusted by determining the Height of the freezing Point above the Ball, and the Height above that Point to which the Oil rises by any other fixed and known Degree of Heat, suppose the Heat of boiling Water, the Heat of a Bath in which Wax swimming and melted by cooling begins to stiffen and loses its Transparency, or the external Heat of a human Body. The Height of the freezing Point F above the Ball of the Thermometer ABC is determined from any two Heights above the Ball to which the Oil rises by two of the three Degrees of Heat now mentioned. Let E and G be

(7)

be the Heights above the Ball to which the Oil rises by the Heat of boiling Water and the external Heat of a human Body, and then $EF : GF :: 34 : 12 :: 17.6$ by the following Scale, and by Division $EF - GF = EB - GB = EG$. $GF :: 11.6$, whence $GF = \frac{6 EG}{11}$ which will give the Distance of the Point F from G, and $GB - GF$ will be the Distance of the same Point from B.

HAVING thus adjusted the Thermometer ABC, it may be kept as a Standard whereby to adjust others whose Stems are too short for the Ascent of the Oil rarefied by the Heat of boiling Water, but long enough for its Ascent when rarefied by the external Heat of a human Body or by any Degree of Heat less than that. Let abc be such a small Thermometer, g the Height to which the Oil rises by the external Heat of a human Body, d, D the Heights in this and the standard Thermometer to which the Oil rises when the two Thermometers are situated alike either in Air or Water, and f the freezing Point of this little Thermometer; and then $GF . DF :: gf . df$, and by Division $GD . DF :: gd . df$, whence $df = \frac{DF \times gd}{GD}$ which will give the Distance of the freezing Point from d, and $db - df$ will be the Distance of the same Point from b.



WHEN a Thermometer is truly adjusted by these Rules, the Heats of Bodies may be found by it, for they will be as the Heights of the Oil above its freezing Point expressed in the Parts of its Scale: For Instance, if the Heights of the Oil above the freezing Point be 18 and 37 Parts of the Scale of the Thermometer, the two Degrees of Heat by which the Oil is rarefied will be as those Numbers, and might be

truly expressed by them, if the Scales of all Thermometers were so divided as to express the same Degrees of Heat by the same Numbers, but as they are generally divided otherwise, in order to do this, they must all be reduced to some one Scale as a Standard, and no one so proper for a STANDARD as Sir *Isaac Newton's*. All Scales may be reduced to this by the following Analogy. *As the Number of Parts of the Scale of the Thermometer which measures the external Heat of a human Body, is to the Number of Parts of the same Scale which measures any other Degree of Heat; so is 12 the Number in Sir Isaac's Scale expressing the external Heat of the Body, to a fourth Number, which will express that other Degree of Heat according to his Scale.* If the Numbers measuring the two Degrees of Heat be 30 and 15 Parts of the Scale of the Thermometer, the corresponding Numbers of Sir *Isaac's* Scale will be 12 and 6, which are the Numbers measuring the external Heat of the Body and the Heat of the *Meridian* Air about the Month of *July*.

By some Experiments made with a Thermometer, it has been found, that the Heat of the warmest parts of the Surface, and by consequence the Heat of the Blood, is much the same in Bodies of all Ages; that the Limbs of old Bodies are considerably colder than those of Bodies in the Vigour of their Age, notwithstanding the Heat of the Blood and inward Parts is much the same in both; that the Heat is nearly the same at all Seasons of the Year, and is but little augmented by either Diet or Exercise; and that the Heat of the Blood in the most ardent Fever does not come up to 17 the greatest Heat of a Bath which a Person can for some time endure with his Hand immersed and kept without Motion. The exact Degrees of Heat under all these Circumstances may easily be determined by a Thermometer rightly adjusted.



Sir ISAAC NEWTON'S SCALE
OF
DEGREES of HEAT.

*Descriptions and Signs of De-
grees of HEAT.*

○



HE Heat of the Air in Winter when Water begins to freeze. This Degree of Heat is known accurately by placing a Thermometer in Snow pressed close together, when Ice begins to thaw.

○, 1, 2

2, 3, 4

THE Heats of the Air in Winter.

THE Heats of the Air in Spring and Autumn.

THE

4, 5, 6		THE Heats of the Air in Summer.
6		THE Heat of the Air at Noon about the Month of <i>July</i> .
12	I	THE greatest Heat which a Thermometer conceives by touching a human Body. This is much the same with the Heat of a Bird sitting upon its Eggs.
14 $\frac{3}{11}$	I $\frac{1}{4}$	THE nearly greatest Heat of a Bath which a Person can for some Time endure with his Hand immerfed and constantly moved. This is nearly the Heat of the Blood coming fresh out of the Body.
17	I $\frac{1}{2}$	THE greatest Heat of a Bath which a Person can for some Time endure with his Hand immerfed and kept without Motion.
20 $\frac{2}{11}$	I $\frac{3}{4}$	THE Heat of a Bath in which Wax swimming and melted by cooling begins to stiffen and loses its transparency.
24	2	THE Heat of a Bath in which Wax swimming by growing hot begins to melt and is preserved in a continued State of Fluidity without Ebullition.
28 $\frac{6}{11}$	2 $\frac{1}{4}$	THE mean Heat between the Heats with which Wax begins to melt and Water boils.
34	2 $\frac{1}{2}$	THE Heat with which Water boils vehemently and a Mixture of two Parts of Lead three Parts of Tin and five Parts of Bismuth by cooling begins to grow stiff. Water begins to boil with a Heat of 33 Parts and by boiling scarcely conceives a Heat of above 34 Parts. But Iron cooling when it has a Heat of 35 or 36 Parts ceaseth to excite

		cite an Ebullition in warm Water falling drop by drop upon it, and when it has a Heat of 37 Parts it ceaseth to excite an Ebullition in cold Water falling upon it in like manner.
40 $\frac{4}{11}$	2 $\frac{3}{4}$	THE least Heat with which a Mixture of one Part of Lead four Parts of Tin and five Parts of Bismuth by heating begins to melt and is preserved in a continued State of Fluidity.
48	3	THE least Heat with which a Mixture of equal Parts of Tin and Bismuth begins to melt. This Mixture by cooling is coagulated with a Heat of 47 Parts.
57	3 $\frac{1}{4}$	THE Heat with which a Mixture of two Parts of Tin and one Part of Bismuth is melted, as also a Mixture of three Parts of Tin and two Parts of Lead. But a Mixture of five Parts of Tin and two Parts of Bismuth by cooling begins to grow stiff with this Heat, and a Mixture of equal Parts of Lead and Bismuth does the same.
68	3 $\frac{1}{2}$	THE least Heat with which a Mixture of one Part of Bismuth and eight Parts of Tin is melted. Tin alone is melted with a Heat of 72 Parts, and by cooling begins to stiffen with a Heat of 70 Parts.
81	3 $\frac{3}{4}$	THE Heat with which Bismuth is melted as also a Mixture of four Parts of Lead and one Part of Tin. But a Mixture of five Parts of Lead and one Part of Tin when it is melted and grows cool begins to stiffen in this Heat.

THE

96	4	THE least Heat with which Lead is melted. Lead by growing hot is melted with a Heat of 96 or 97 Parts and by growing cool begins to stiffen with a Heat of 95 Parts.
114	$4\frac{1}{4}$	THE Heat with which Bodies on Fire by cooling wholly cease to shine in the Darknes of the Night, and on the other Hand that with which Bodies growing hot begin to shine in the Darknes of the Night but with the smallest Light that can scarcely be perceived. By this Heat a Mixture of equal Parts of Tin and <i>Regulus martis</i> begins to melt, and a Mixture of seven Parts of Bismuth and four Parts of the same <i>Regulus</i> by cooling begins to stiffen.
136	$4\frac{1}{2}$	THE Heat with which Bodies on Fire shine in the Darknes of the Night but not at all in Twilight. With this Heat both a Mixture of two Parts of <i>Regulus martis</i> and one Part of Bismuth and a Mixture of five Parts of <i>Regulus martis</i> and one Part of Tin by cooling begins to stiffen. <i>Regulus</i> by it self begins to stiffen with a Heat of 146 Parts.
161	$4\frac{3}{4}$	THE Heat with which Bodies on Fire manifestly shine in the Twilight just before the rising or after the Setting of the Sun but not at all or but very obscurely in clear Daylight.
192	5	THE Heat of red-hot Coals in a small Kitchen-Fire made of bituminous Pit-Coals and burning without the Help of Bellows. The same is the Heat of Iron heated in such a Fire as hot

hot as it can be. The Heat of a small Kitchen-Fire made of Wood is a little greater, *viz.* of 200 or 210 Parts. And the Heat of a great Fire is still greater especially if it be blown with Bellows.

IN the first Column of this TABLE are Degrees of Heat computed in Arithmetick Proportion, beginning the Computation from the Heat with which Water begins to freeze as the lowest Degree of Heat or as the common Boundary of Heat and Cold, and making the external Heat of the human Body to consist of twelve Parts. In the second Column are Degrees of Heat in Geometrick Proportion so as that the second Degree is double of the first, the third double of the second, the fourth of the third, and the first is the external Heat of the Body which by not being perceived by the Senses may be said to be made equal to them. It is manifest by this Table that the Heat of boiling Water is almost three Times greater than the Heat of the human Body, and the Heat of Tin beginning to melt six Times greater, and the Heat of Lead beginning to melt eight Times greater, and the Heat of *Regulus* beginning to melt twelve Times greater, and the ordinary Heat of a Kitchen-Fire sixteen or seventeen Times greater than the same Heat of the human Body.

THIS Table was constructed by the Help of a Thermometer and a red-hot Iron. By the Thermometer I found the Measure of all the Degrees of Heat as far as that with which Tin is melted, and by a heated Iron I found the Measure of the rest. For the Heat which heated Iron communicates in a given Time to cold Bodies contiguous to it, that is the Heat which the Iron loses in a given Time is as the whole Heat of the Iron. And therefore if the Times of cooling be taken equal the Degrees of Heat will
be

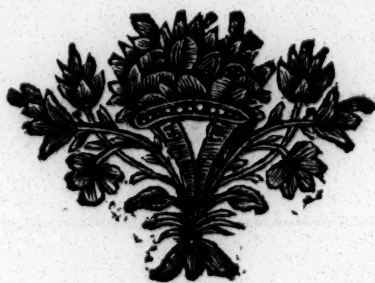
be in Geometrick Proportion, and for that reason may be easily found by a Table of Logarithms.

FIRST therefore I found by a Thermometer constructed of Linseed-Oil that if the Oil when the Thermometer was placed in Snow beginning to melt possessed a Space of 10000 Parts, the same Oil rarefied by the first Degree of Heat or the Heat of the human Body possessed the Space 10256, and by the Heat of Water just beginning to boil the Space 10705, and by the Heat of Water boiling vehemently the Space 10725, and by the Heat with which melted Tin by cooling begins to stiffen and put on the Consistence of an Amalgam the Space 11516 and when it is grown intirely stiff the Space 11496. Therefore the Oil was rarefied and dilated in the Proportion of 40 to 39 by the Heat of the human Body, in the Proportion of 15 to 14 by the Heat of boiling Water, in the Proportion of 15 to 13 by the Heat of Tin cooling when it begins to coagulate and stiffen, and in the Proportion of 23 to 20 by the Heat with which Tin cooling grows altogether stiff. The Rarefaction of Air with an equal Heat was ten Times greater than the Rarefaction of Oil, and the Rarefaction of Oil about fifteen Times greater than the Rarefaction of Spirit of Wine. And from these Things found, by supposing the Heats of Oil to be proportional to its Rarefaction, and writing 12 Parts for the Heat of the human Body, the Heat of Water when it begins to boil comes out 33 Parts and when it boils vehemently 34 Parts; and the Heat of Tin when it either begins to melt or by cooling begins to stiffen and put on the Consistence of an Amalgam 72 Parts, and when by cooling it grows stiff and hard 70 Parts.

THESE being known, that I might investigate the rest, I heated a sufficiently thick Piece of Iron red-hot, and taking it out of the Fire with a Pair of Tongs likewise red-hot, I placed it in a cold Place where the
Wind

Wind blew constantly, and putting upon it Bits of divers Metals and other liquefiable Bodies I marked the Times of cooling till all the Bits having lost their Fluidity grew stiff, and the Heat of the Iron became equal to the Heat of the human Body. Then by supposing that the Heats of the Iron and Parts beginning to stiffen above the Heat of the Atmosphere found by the Thermometer are in Geometrick Progression when the Times are in the Arithmetick Progression, all the Degrees of Heat were discovered. But I placed the Iron not in a still and calm Air but in Wind blowing uniformly that the Air heated by the Iron might be always carried off by the Wind, and cold Air succeed into its place with an uniform Motion. For so equal Parts of Air are heated in equal Times, and conceive a Heat proportional to the Heat of the Iron.

BUT the Heats so found have the same Proportion amongst themselves with the Heats found by the Thermometer, and therefore I have rightly taken the Rarefactions of Oil proportional to its Heat.





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THERMOMETERS are made
and truly adjusted by Mr. *Edward*
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